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POLICY CONSIDERATIONS AND MEASURES TO REDUCE THE LIKELIHOOD OF VESSEL COLLISIONS WITH GREAT WHALES

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Abstract: Both globally and along the North American east coast of the Atlantic Ocean, reported ship strikes of great whales have been at historic highs during the past fifteen years. Ship strikes present a particularly grave threat to the North Atlantic right whale, given its severely depleted population status and the fact that right whales live, breed, and raise their young in areas that are heavily used by massive commercial vessels that travel at lethal speeds. Fortunately, decreasing the possibility of lethal strikes is not complicated—seasonally slow down vessels to ten knots and/or re-route them around those areas where right whales are known to aggregate. Here I describe the plight of the right whale and a series of scientific studies that can, and in some instances have, been used to facilitate legally defensible and common sense government measures to protect great whales.

Introduction

The National Marine Fisheries Service (NMFS), a unit of the National Oceanic and Atmospheric Administration (NOAA) is charged with managing great whale populations. For those species that also are listed under the Endangered Species Act (ESA), NMFS takes on added obligations, including designating critical habitat, developing recovery plans, and reducing incidental take from commercial fishery operations.[1] One such species of great whales, the North Atlantic right whale

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[1] 16 U.S.C. §§ 1531–1544 (2006). A species that is listed as endangered or threatened under the ESA or below its optimum sustainable population is by definition "depleted" under section 2 of the Marine Mammal Protection Act (MMPA) of 1972. 16 U.S.C. § 1362(1) (2006). The MMPA in turn requires NMFS to develop a plan to reduce mortality of and serious injury to such populations (referred to as "strategic stocks") as a result of commercial fishing operations. 16 U.S.C. § 1387(f) (2006); Advance Notice of Proposed Rulemaking (ANPR) for Right Whale Ship Strike Reduction, 69 Fed. Reg. 41,446, 41,447 (July 9, 2004) (to be codified at 50 C.F.R. pt. 224).

(*Eubalaena glacialis*), which ranges from Florida to the Bay of Fundy in Canada, is endangered throughout its entire range.[2] Historically, their numbers were reduced by whaling, which was once the fifth largest industry in the United States.[3] However, despite the international legal protection from whaling since the 1930s,[4] right whale population remains small, with the population currently estimated at around 350.[5]

Scientific research identifies two prime factors for the inability of the right whale to recover despite its protection from whaling—being struck by commercial vessels[6] and becoming entangled in fishing gear, with vessel collisions alone accounting for more than half of deaths based on necropsies.[7] This is a problem of particular concern given present trends that suggest the species will likely be extinct within two centuries.[8]

In this Paper, I consider the nature of commercial vessel collisions with great whales and actions that regulators are taking and might take

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[2] Hal Caswell et al., *Declining Survival Probability Threatens the North Atlantic Right Whale*, 96 Proc. Nat'l Acad. Sci. 3308, 3308 (1999); Amy R. Knowlton et al., *Reproduction in North Atlantic Right Whales* (Eubalaena glacialis), 72 Canadian J. Zoology 1297, 1297 (1994).

[3] Lance E. Davis et al., In Pursuit of Leviathan: Technology, Institutions, Productivity, and Profits in American Whaling, 1816–1906, at 4 (1997).

[4] Convention for the Regulation of Whaling art. 4, Sept. 24, 1931, 49 Stat. 3079, 155 L.N.T.S. 349 (forbidding, in pertinent part, the taking or killing of right whales); *see* International Convention for the Regulation of Whaling sched. ¶ 2, Dec. 2, 1946, 62 Stat. 1716, 161 U.N.T.S. 72 [hereinafter ICRW] (amended 2008); International Agreement for the Regulation of Whaling art. 4, June 8, 1937, 52 Stat. 1460, 190 L.N.T.S. 79; *see also* Whaling Convention Act (WCA) of 1949, 16 U.S.C. §§ 916–916(l) (2006). Regulations banning the taking of right whales except by indigenous peoples are found in the "Schedule" (the regulations) appended to the ICRW and contained therein; they remain part of the Schedule to this day. ICRW, *supra*, sched. ¶ 2; Jeremy Firestone & Jonathan Lilley, *An Endangered Species: Aboriginal Whaling and the Right to Self-Determination and Cultural Heritage in a National and International Context*, [2004] 34 Envtl. L. Rep. (Envtl. Law Inst.) 10,763, 10,771–72 (Sept. 2004); *see also* Jeremy Firestone & Jonathan Lilley, *Aboriginal Subsistence Whaling and the Right to Practice and Revitalize Cultural Traditions and Customs*, 8 J. Int'l Wildlife L. & Pol'y 177, 194–95 (2005), *available at* http://www.ocean.udel.edu/cms/jfirestone/MakahWhalingJIWLP2005.pdf.

[5] Scott D. Kraus et al., *North Atlantic Right Whales in Crisis*, 309 Science 561, 561 (2005).

[6] Vessels also cause acoustic impacts on marine mammals. *See* Jeremy Firestone & Christina Jarvis, *Response and Responsibility: Regulating Noise Pollution in the Marine Environment*, 10 J. Int'l Wildlife L. & Pol'y 109, 109, 145–46 (2007).

[7] Regina Campbell-Malone et al., *Gross and Histologic Evidence of Sharp and Blunt Trauma in North Atlantic Right Whales* (Eubalaena Glacialis) *Killed by Vessels*, 39 J. Zoo & Wildlife Med. 37, 37 (2008); *see also* Ne. Fisheries Sci. Ctr., U.S. Dep't of Commerce, NOAA Technical Memorandum NMFS-NE-201, U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments—2006, at 9–11 (Gordon T. Waring et al. eds., 2007) [hereinafter Marine Mammal Stock Assessments], *available at* http://www.nefsc.noaa.gov/nefsc/publications/tm/tm201/tm201.pdf.

[8] Caswell et al., *supra* note 2, at 3312.

to reduce the incidence and severity of such collisions. Although vessel strikes of great whales is an issue of international concern,[9] in thinking further about this question, I focus on ship strikes of North Atlantic right whales, and more particularly on work that either my colleagues or I have conducted on mitigating encounter probabilities in right whale habitat areas,[10] modeling right whale migration in areas for which data is sparse,[11] and examining the effects of ship speed and mass on the potential collision severity.[12] I am indebted to my colleagues and would direct anyone interested in this topic to search out the primary source material from which this paper is drawn.

I. Background on Collisions

The extent to which ship collisions contribute to mortality presents a challenge to scientists because ship collisions are rarely reported. Instead, scientists must attempt to decipher clues regarding the cause of death during whale necropsies—essentially akin to "whale CSI." Despite their best efforts, in some instances, the cause of death cannot be determined. Examinations by scientists nevertheless led them to attribute approximately thirty-five percent of all documented right whale deaths from 1970 to 1999 to ship strikes, with the percentage increasing to forty-seven percent during the last ten years of that thirty year period.[13]

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[9] *See, e.g.*, International Whaling Commission [IWC], 60th Annual Meeting of the IWC, Santiago, Chile, June 23–27, 2008, *Agenda Item 15: Report of the Conservation Committee*, at 1–4, IWC Doc. IWC/60/Rep 5 (June 17, 2008), http://www.iwcoffice.org/_documents/commission/IWC60docs/60-Rep5.pdf.

[10] Angelia S.M. Vanderlaan et al., *Probability and Mitigation of Vessel Encounters with North Atlantic Right Whales*, 6 Endangered Species Res. 273 (2009) [hereinafter Vanderlaan et al., *Probability and Mitigation of Vessel Encounters*]; Angelia S.M. Vanderlaan et al., *Reducing the Risk of Lethal Encounters: Vessels and Right Whales in the Bay of Fundy and on the Scotian Shelf*, 4 Endangered Species Res. 283 (2008) [hereinafter Vanderlaan et al., *Reducing the Risk of Lethal Encounters*].

[11] Jeremy Firestone et al., *Statistical Modeling of North Atlantic Right Whale Migration Along the Mid-Atlantic Region of the Eastern Seaboard of the United States*, 141 Biological Conservation 221 (2008).

[12] Angelia S.M. Vanderlaan & Christopher T. Taggart, *Vessel Collisions with Whales: The Probability of Lethal Injury Based on Vessel Speed*, 23 Marine Mammal Sci. 144 (2007); Chengfeng Wang et al., *Using Ship Speed and Mass to Describe Potential Collision Severity with Whales: An Application of the Ship Traffic, Energy and Environment Model (STEEM)*, 2007 Transp. Res. Bd. Ann. Meeting Paper No. 07-2368 (TRB 86th Annual Meeting Compendium of Papers CD-ROM, 2007).

[13] Amy R. Knowlton & Scott D. Kraus, *Mortality and Serious Injury of Northern Right Whales* (Eubalaena glacialis) *in the Western North Atlantic Ocean*, 2 J. Cetacean Res. & Mgmt. 193, 195 (Special Issue 2001); *see* David W. Laist et al., *Collisions Between Ships and Whales*, 17 Marine Mammal Sci. 35, 52–53 (2001). It is worth noting that these threats are not unique to the right whale; fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), and minke

The increased percentage of all right whale deaths attributed to ship strikes over time might be attributed to the fact that the number of commercial vessels has increased three-fold over the past fifty years, with ship size (mass) and speed increasing as well.[14] In fact, the trend of increasing whale deaths from ship strikes over the period 1972 to 2002 appears to follow a several-year lag of increasing numbers of commercial vessels.[15]

Government officials who are tasked with responsibility for right whale protection must be mindful that ship-whale collisions have both geospatial and biophysical components. They must consider not only where interactions are most likely to occur in time and in space, but, in addition, the magnitude of the force of an impact on a whale. In other words, successful management of vessel strikes depends on the ability to understand the risk of an interaction between a vessel and a whale at a given point and time as well as the effects of that interaction. Government officials are essentially left with two possible options to reduce collision fatality risk to right whales—re-route vessels and thereby decrease the probability of a collision and/or impose speed restrictions on vessels to decrease the impact-force should any collision occur.[16]

There are benefits and costs to both re-routing and speed restrictions. From a whale conservation perspective, re-routing is preferred because it decreases the probability of a collision, thus hopefully eliminating collisions that would otherwise occur. If we assume that commercial vessels presently take the shortest path (accounting for depth limitations) from one point to another given additional fuel, labor, and other time costs associated with taking any other path, re-routing would

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(*Balaenoptera acutorostrata*) whales also are victims of vessel strikes. *See* Aleria S. Jensen & Gregory K. Silber, U.S. Dep't of Commerce, NOAA Technical Memorandum NMFS-OPR-25, Large Whale Ship Strike Database 2 (2004), *available at* http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/lwssdata.pdf; Marine Mammal Stock Assessments, *supra* note 7, at 140 app. II; Laist et al., *supra*, at 63 app. I. However, per capita, right whales are most likely to be struck. Vanderlaan & Taggart, *supra* note 12, at 144–45.

[14] *See* Vanderlaan et al., *Probability and Mitigation of Vessel Encounters*, *supra* note 10, at 274.

[15] *See id.* at 282.

[16] Speed restrictions were found effective in protecting Florida manatees from watercraft-related deaths. David W. Laist & Cameron Shaw, *Preliminary Evidence That Boat Speed Restrictions Reduce Deaths of Florida Manatees*, 22 Marine Mammal Sci. 472, 476–77 (2006). In 2006, NOAA proposed rules to reduce vessel speeds in certain areas. Proposed Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales, 71 Fed. Reg. 36,299 (proposed June 26, 2006). But it was not until late 2008 that the final rule was published. Final Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales, 73 Fed. Reg. 60,173 (Oct. 10, 2008) (to be codified at 50 C.F.R. pt. 224); *see infra* notes 39–44 and accompanying text.

result in increased distance and time to reach the same destination. Not only does re-routing have fiscal consequences for vessel owners, it has environmental and human health consequences as the result of the concomitant emission of additional conventional pollutants like particulate matter and SO_2 and long-term consequences for the climate, including warming temperatures, sea-level rise, and ocean acidification as a result of greenhouse gas (GHG) emissions.[17] Good policy analysis would consider all of these consequences in any risk tradeoff.

Ship speed restrictions to protect a species likely have particular merit where diversions of commercial vessels are infeasible due to bathymetric constraints such as when a species congregates in close proximity to a port.[18] In those instances, the only other option may be a politically charged ship diversion and port closure. Speed restrictions also have merit when shifting vessel traffic would result in an unacceptable increased risk to another species. Like vessel re-routing, speed restrictions increase costs to commercial vessel operators in terms of labor and other time costs; however, because vessels would travel slower than they would otherwise, they would consume less fuel, thereby saving the ship owner money and decreasing air pollution.

II. Background on Right Whale Habitat Areas and Migration

Right whales are known to aggregate in five areas—which I refer to as habitat areas. The five areas are Cape Cod Bay, the Great South Channel off of Massachusetts, the winter calving grounds adjacent to the port of Jacksonville, Florida, and two areas in Canadian waters—the Bay of Fundy and Roseway Basin. Surveys have been conducted of right whale populations—right whales are counted by individuals stationed on planes (or ships) that fly aerial transects and the counts are then adjusted for the level of effort (the amount of time employed counting

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[17] *See* James J. Corbett et al., *Mortality from Ship Emissions: A Global Assessment*, 41 Envtl. Sci. Tech. 8512, 8512, 8517 (2007) (stating that "shipping related [particulate matter] emissions contribute approximately 60,000 deaths annually at a global scale"); Chengfeng Wang et al., *Improving Spatial Representation of Global Ship Emissions Inventories*, 42 Envtl. Sci. Tech. 193, 193 (2008). *See generally* Øyvind Buhaug et al., Int'l Maritime Org., MEPC 58/INF.6, Updated Study on Greenhouse Gas Emissions from Ships: Phase I Report (2008), *available at* http://www.imo.org/includes/blastDataOnly.asp/data_id%3D23703/INF-6.pdf (discussing greenhouse gas emissions from shipping). Climate change may have implications for right whales. Charles H. Greene & Andrew J. Pershing, *Climate and the Conservation Biology of North Atlantic Right Whales: The Right Whale at the Wrong Time?* 2 Frontiers in Ecology & Env't 29, 31–33 (2004).

[18] *See* Vanderlaan et al., *Probability and Mitigation of Vessel Encounters*, *supra* note 10, at 283.

on a given transect).[19] A photographic catalogue of individual right whales, which is feasible given the less than 400 members of the species, and which is based on distinctive markings, features, and unfortunate wounds from fishing gear and ship collisions, is also maintained.[20] Because the foraging and reproductive behaviors of right whales provide scientists with predictable spatial and temporal periods in which to conduct surveys, those surveys in conjunction with the photographic catalogue provide a good understanding of right whale behavior at the species level (aggregations by time of year, pod size, sex, age, and location, etc.) in the five habitat areas.

For example, we know that the southern calving grounds are primarily populated by females, calves, and juveniles—the most important members of an endangered population—during the months of December through March.[21] Unfortunately, much less is known about right whale migration because of the dearth of survey data in migratory zones. This is due in part to budgetary constraints and in part to the difficulties posed in observing migrating whales, as they spend much less time at the surface and cover large distances. Right whales in particular present difficulties because they have no dorsal fin. A lack of knowledge about migration unfortunately has consequences because, for example, more than a quarter of all documented right whale vessel strike mortalities since 1970 have occurred in the mid-Atlantic migratory corridor.[22] That figure, however, vastly understates the risk posed to the population during migration because the population subset that migrates twice yearly through the corridor is comprised disproportion-

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[19] *See, e.g.*, Misty Niemeyer et al., U.S. Dep't of Commerce, Northeast Fisheries Science Center Reference Document 08-06, North Atlantic Right Whale Sighting Survey (NARWSS) and Right Whale Sighting Advisory System (RWSAS): 2007 Results Summary (2008), *available at* http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0806/crd0806.pdf (discussing the results of a sighting survey); National Oceanic and Atmospheric Administration, Mid-Atlantic Sightings Archive, http://www.nero.noaa.gov/shipstrike/doc/Historical%20sightings.htm (last visited Mar. 24, 2009).

[20] *See* New England Aquarium, The North Atlantic Right Whale Catalog, http://rwcatalog.neaq.org/Default.aspx (read the "Terms of Use" and click on the "I Agree" hyperlink) (last visited Mar. 24, 2009).

[21] *See* Scott D. Kraus et al., *Migration and Calving of Right Whales* (Eubalaena glacialis) *in the Western North Atlantic*, *in* Right Whales: Past and Present Status 139, 141–43 (Robert L. Brownell et al. eds., 1986).

[22] Amy R. Knowlton et al., Right Whale Sightings and Survey Effort in the Mid-Atlantic Region: Migratory Corridor, Time Frame, and Proximity to Port Entrances 2 (2002), *available at* http://www.nero.noaa.gov/shipstrike/ssr/midatanticreportrFINAL.pdf.

ately of reproductively mature females, pregnant females, juveniles, and young calves.[23]

III. Right Whale Migration, Vessel Encounters, and Lethality of Ship Strikes

A. *Right Whale Migration*

Intuitively, ships and whales are more likely to interact frequently in those areas and times where the density of each is high. The mid-Atlantic is home to many important ports and port complexes (for example, Savannah, Charlestown, Norfolk, Baltimore, the Delaware Bay Port complex, and New York/New Jersey) and coastwise vessel traffic in the mid-Atlantic is uniformly heavy throughout the year. As a result, the relative probability of a vessel collision at a given time and location in the mid-Atlantic is primarily being driven by right whale behavior. Understanding migration thus would be useful in identifying those areas and times in which the probability of a vessel collision may be high. Given the dearth of survey data in the mid-Atlantic corridor (for example, of the 25,259 right whale observations in the dataset, only 126 observations were made during the first half of the year between 32°N and 40°N latitude, which is the heart of the mid-Atlantic migratory corridor), we attempted to model right whale occurrence temporally and spatially in that corridor.[24] Indeed, if statistical models are predictive of actual migration behavior, they can then be used to create appropriate mitigation measures and to guide survey efforts in migratory corridors.

Our modeling indicates that right whales depart the southern calving grounds adjacent to Jacksonville, Florida in early to mid-March.[25] Right whales in pods containing one or more calves were found to begin their northerly migration several days after right whales in pods without calves.[26] Given the paucity of data on which the model is built, not surprisingly, the range of departure dates is fairly large—plus or minus fifteen days from the mean departure date.[27] We also were able to calcu-

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[23] *See* Masami Fujiwara & Hal Caswell, *Demography of the Endangered North Atlantic Right Whale*, 414 Nature 537, 539 (2001); Kraus et al., *supra* note 21, at 141–43; Leslie I. Ward-Geiger et al., *Characterization of Ship Traffic in Right Whale Critical Habitat*, 33 Coastal Mgmt. 263, 273–74 (2005), *available at* http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/critical_habitat_traffic.pdf.

[24] Firestone et al., *supra* note 11, at 223.

[25] *Id.* at 225, 230.

[26] *See id.* at 225, 228.

[27] *Id.* at 228.

late the average travel time from the Florida-Georgia border to the tip of Long Island and found it to be slightly more than twenty days, corresponding to a mean migration/displacement rate of about 1.6 knots (3 km/hr).[28] In sum, because the model predicts times of year during which right whales can be expected to be adjacent to mid-Atlantic port entrances, these results provide the basis for port-specific, narrowly tailored, date-range specific speed reductions in the vicinity of those ports.

B. *Vessel-Right Whale Encounter Probabilities and Mitigation Measures*

As noted above, right whales use five habitat areas. In each area, we obtained effort-correct right whale survey data which reflects relative right whale occurrence and absence.[29] To determine the relative probability of ship occurrence we used ship location data reported by the Voluntary Observing Ships (VOS) as part of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS).[30] ICOADS, which is maintained by NOAA, consists in pertinent part of voluntary reporting by ships of oceanographic and climatic data; however, here, we used the database solely to identify ship type and location. Although participation in the VOS is voluntary and reporting at any given time and location by participating ships is likewise voluntary, the resulting dataset generates reliable estimates of the relative probability of occurrence at any given point and time.[31]

Using advanced geographic information system (GIS) techniques, we examined the encounter probabilities in each of the five habitat areas and the benefits of diverting vessel traffic around the heaviest aggregations of right whales at three of those areas. Although the greatest relative encounter probabilities are found in the Bay of Fundy and the southern calving grounds, the proximity of the southern calving grounds to the entrance to the port of Jacksonville makes it impracticable to reroute vessels around the aggregation of right whales, short of closing

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[28] *Id.* at 230. One knot equals one nautical mile per hour. One nautical mile equals 1.15 miles.

[29] Vanderlaan et al., *Probability and Mitigation of Vessel Encounters*, *supra* note 10, at 275–76; *see also* Firestone et al., *supra* note 11, at 223 (describing method of obtaining effort-corrected survey data from the North Atlantic Consortium's Sightings Database).

[30] *See* Vanderlaan et al., *Probability and Mitigation of Vessel Encounters*, *supra* note 10, at 276. This information is compiled in the publicly accessible ICOADS database. *See* National Oceanic and Atmospheric Administration, International Comprehensive Ocean-Atmosphere Data Set, http://icoads.noaa.gov/ (last visited Mar. 24, 2009).

[31] *See* Wang et al., *supra* note 17, at 194, 198.

that port during the winter months.[32] Thus, speed reductions appear to be the most feasible option for that area. For similar reasons, the same holds true in Cape Cod Bay.[33] As for the Bay of Fundy,[34] Roseway Basin,[35] and the Great South Channel,[36] shifting vessels decreases the absolute probability of a vessel encounter—defined as a vessel in the same five-minute[37] latitude-longitude box—by eighty-two percent, eighty-five percent, and thirty-six percent, respectively.[38] Although it might appear that shifting vessels in the Great South Channel would result in substantially smaller benefits than in the Roseway Basin, the Great South Channel covers a much larger area and importantly has approximately twenty

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[32] *See* Vanderlaan et al., *Probability and Mitigation of Vessel Encounters*, *supra* note 10, at 281, 283.

[33] *Id.*

[34] In late 2002, the International Maritime Organization (IMO) adopted an amended traffic-separation scheme for vessel traffic in the Bay of Fundy for the purpose of decreasing the likelihood of vessel encounters with right whales. *See* Int'l Maritime Org.[IMO], *New and Amended Traffic Separation Schemes*, at Annex 5, IMO Doc. COLREG.2/Circ.52 (Jan. 6, 2003), *available at* http://www.imo.org/includes/blastDataOnly.asp/data_id%3D6679/52.pdf; Canadian Whale Institute, Bay of Fundy Shipping Lanes, http://rightwhale.ca/shippinglanes-routesnavigation_e.php (last visited Mar. 24, 2009). Our work, which is based on pre-amendment traffic data, supports the decision to change the traffic routes, which was based on our collaborator Christopher Taggart's earlier work using different ship data. *See* Vanderlaan et al., *Reducing the Risk of Lethal Encounters*, *supra* note 10, at 288, 290; *see also* Canadian Whale Institute, *supra* (citing Dr. Christopher Taggart's probability analyses as an impetus for changing the traffic routes).

[35] In 2007, the IMO designated the Roseway Basin as a *recommended* "Area to be Avoided" from June 1 until December 31 of each year. IMO, *Routeing Measures Other Than Traffic Separation Schemes*, 9–10, IMO Doc. SN.1/Circ.263 (Oct. 23, 2007), *available at* http://www.imo.org/includes/blastDataOnly.asp/data_id%3D20339/263.pdf. This decision was implemented by Transport Canada on June 1, 2008. Press Release, Transport Canada, Roseway Basin (June 18, 2008), *available at* http://www.tc.gc.ca/mediaroom/releases/atl/2008/08-a004e.htm.

[36] In December 2008, the IMO designated the Great South Channel as a recommended seasonal Area to be Avoided. IMO, Routeing Measures other than Traffic Separation Schemes, Ref. T2-OSS/2.7.1, SN.1/Circ.272 (10 Dec. 2008), available at http://www.nero.noaa.gov/shipstrike/doc/GSC_ATBA_IMO_circular.pdf.

[37] Each degree of latitude and longitude is divided into sixty minutes.

[38] Vanderlaan et al., *Probability and Mitigation of Vessel Encounters*, *supra* note 10, at 282; James J. Corbett et al., Presentation at the 2007 North Atlantic Right Whale Consortium Meeting, Estimating Encounter Probabilities: Comparative Quantitative Estimates of Decreased Encounter Probabilities in the Right Whale Habitat Through Shifting of Vessel Traffic (Oct. 25, 2007) (unpublished presentation, on file with author). These percentages are contingent both on the ship data set employed and on the domain over which vessels are shifted. *See* Vanderlaan et al., *Reducing the Risk of Lethal Encounters*, *supra* note 10, at 290. For example, while we found an 85% decrease in the Bay of Fundy, our collaborators found a similar 90%±4.2% decrease in the relative probability of a vessel collision in the "whale conservation area" in the Bay of Fundy from shifting the lanes, but only a 40% decrease when they considered the movement of vessels over a larger domain, accounting for the entire shift of the traffic separation scheme. *See id.*

times the number of ship-whale encounters than occur in the Roseway Basin.[39] On the other hand, being a relatively confined area, the entire commercial fleet could divert around Roseway Basin with only minor inconvenience (an additional eight to thirty kilometers depending on the initial route of the ship). In contrast, the route we proposed for the Great South Channel, at approximately 259 nautical miles (about 480 km) is considerably longer than the existing route of approximately 188 nautical miles (about 348 km).[40] For a container ship traveling at a speed of twenty knots that Great South Channel diversion would translate into slightly more than three and a half hours. For tankers, general cargo ships, or bulk carriers, which travel at a speed closer to thirteen knots, re-routing would add five and a half hours.

C. *The Effects of Ship Speed and Mass on Collision Severity*

Lastly, we examined how ship speed and mass affect collision severity using historical worldwide data on ship strikes of large whales.[41] The data include the mass and speed of vessels that have collided with whales and the outcome of the collision—no injury, minor injury, severe injury, or death. Using equations from basic physics on the momentum forces that prevail when two moving bodies collide, we were able to plot the collision impact-force against the probability of death. From that, we were able to determine that a whale struck by a large commercial vessel (greater than 5000 dead weight tons) that is traveling at speeds of eighteen knots or greater is likely to have lethal injuries, while a collision with a vessel traveling at ten knots is likely to be non-lethal.[42]

We also were able to determine that for a smaller ship—one with a mass of approximately 500 metric tons or less—its mass is as or more important than its speed in determining its potential impact-force.[43] On the other hand, when a ship is greater than 500 metric tons, the speed it is travelling dominates the impact-force equation.[44] Therefore,

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[39] Corbett et al., *supra* note 38. The Bay of Fundy has thirty-five percent more encounters than the Great South Channel. *Id.*

[40] Vanderlaan et al., *Probability and Mitigation of Vessel Encounters*, *supra* note 10, at 282, 284. We chose the Great South Channel route based on bathymetric constraints, a desire to minimize right whale encounters, and because it followed to the extent possible existing vessel traffic patterns. *Id.*

[41] *See generally* Wang et al., *supra* note 12.

[42] *Id.* at 14.

[43] *Id.* at 11.

[44] *Id.*

speed represents the most important variable to control if policymakers seek to reduce the potential impact-force of commercial vessels—and in any event, it is not realistic to change ship mass—and hence the lethality of those vessels to large whales.

Discussion and Conclusion

Both globally and along the North American east coast of the Atlantic Ocean, reported strikes of great whales have been at historic highs over the past fifteen years. Ship strikes present a particularly grave threat to the North Atlantic right whale, given its severely depleted population status and the fact that right whales live, breed, and raise their young in areas that are heavily used by massive commercial vessels that move at lethal speeds. Fortunately, decreasing the possibility of lethal strikes is not complicated—slow vessels down to ten knots and/or re-route them around those areas where right whales are known to aggregate. As I have described above, scientific methods based on probability theory, spatial analysis, physics, and statistics can, and in some instances have, been used to facilitate legally defensible and common sense government measures to protect great whales.

At least in those instances where policy measures—such as the route adjustments in the Bay of Fundy and Roseway Basin—result in little additional cost and inconvenience to the shipping industry, it has enthusiastically supported approaches that will unquestionably lead to the decrease in the probability of ship strikes. The Bush administration moved much more slowly than Canadian officials to implement binding measures in U.S. waters. Although the Bush administration first considered promulgating a speed-reduction rule in 2004,[45] it was not until the waning days of the administration in late 2008 that speed restrictions were imposed.[46] One might surmise that the Bush administration's "go slow" approach to rulemaking was influenced by concerns raised by the commercial vessel industry because "go slow" restrictions would have a much greater effect on vessel operators. Notably, when the rule was finally promulgated, the industry did not stand in its way, although it did receive a number of concessions. In principal part, the rule has established seasonal speed restrictions in four areas

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[45] Advance Notice of Proposed Rulemaking (ANPR) for Right Whale Ship Strike Reduction, 69 Fed. Reg. 41,446, 41,447 (July 9, 2004) (to be codified at 50 C.F.R. pt. 224).

[46] Final Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales, 73 Fed. Reg. 60,173 (Oct. 10, 2008) (to be codified at 50 C.F.R. pt. 224).

defined by latitude and longitude: the southern calving grounds, Cape Cod Bay, the Great South Channel, and off of Race Point, which is to the north and east of Cape Cod.[47] In addition, speed restrictions will apply in the mid-Atlantic, but unlike the proposed rule, will only extend twenty nautical miles from the coast.[48] The rule also calls for voluntary speed restrictions in other areas when right whale aggregations are found; this voluntary call also was a step back from what had been mandatory in the proposed rule.[49] Perhaps the most important change over that which was proposed was the inclusion of a sunset provision, with the rule now expiring after five years.[50] That leaves it to future administrations to see whether they too can demonstrate the courage to protect the right whale.

[47] *Id.* at 60,187–88.
[48] *Id.* at 60,178–79, 60,187–88.
[49] *See id.* at 60,180, 60,186.
[50] *Id.* at 60,188.